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ABSTRACT

This paper reports on the development and implementation of a flexible audit trail system comprising a library of auditing functions that can be embedded into interactive courseware and customized to the requirements of researchers and developers. A series of essential criteria considered critical to the development of a robust, flexible audit trail system were devised. The six criteria established were: flexibility, efficiency, scalability, portability, retrospective compatibility, and ease of use. The paper presents a case study involving the pilot implementation of the system within a piece of medical courseware. The results of this study demonstrate the general utility of evaluation based on audit trails. Results also provided the courseware's developers with valuable information on how students used the courseware generally and, more specifically, on how they completed one particular interactive task. (AEF)

Flexible Audit Trailing in Interactive Courseware

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Abstract
This paper reports on the development and implementation of a flexible audit trail system comprising a library of auditing functions that can be embedded into interactive courseware and customised to the requirements of researchers and developers. It presents a case study involving the pilot implementation of the system within a piece of medical courseware. The results of this study demonstrate the general utility of evaluation based on audit trails. They also provided the courseware's developers with valuable information on how students used the courseware generally and, more specifically, on how they completed one particular interactive task.

Audit Trails: One Component of Electronic Evaluation

We are currently developing a system of electronic evaluation that addresses three distinct types of evaluation: (i) students' activities and movements within individual pieces of courseware (ii) students' use of and movements between pieces of courseware, and (iii) students' perceptions of pieces of courseware. The first of these components, based on audit trails, provides developers, evaluators and researchers in the area of educational technology with an invaluable mechanism to record and analyse students' activities within a variety of electronic environments. Misanchuk and Schwier (1992) define and ascribe four primary roles to audit trails:

- Formative evaluation of instructional design; that is, evaluation aimed at optimising the performance of a piece of courseware.
- Basic research in instructional design; for example, investigating how different users interact with a piece of courseware.
- Usage audits for unstructured or public environments; that is, determining which paths or components of a piece of courseware are most visited by users.
- Counselling and advising; that is, supporting the user's decision making within a piece of courseware.

With these four roles in mind we devised a series of essential criteria that we considered critical to the development of a robust, flexible audit trail system. The six criteria we established were:

- Flexibility - the system should be capable of fulfilling all of the roles of audit trails outlined by Misanchuk and Schwier (1992). It should be able to store a range of data types.
- Efficiency - the system should manage data efficiently. It should only record and deliver information specifically requested by the developer/researcher and any information collected should be clearly associated with a specific user action or activity.
- Scalability - the system should be capable of handling an unlimited number of records and of dynamically adding or deleting records.
- Portability - the system should adopt an architecture that can be implemented across a range of authoring environments/software.
- Retrospective compatibility – the system should be easily fitted to existing courseware.
- Ease of use - the system should be easily implemented and require minimal programming effort by developers/researchers.

The first two of these criteria are general and address the various roles of audit trails and the need to provide a robust yet flexible framework and to avoid indiscriminate data collection. The third and fourth criteria are essentially technical requirements that speak to the need to develop a robust yet generic audit trail system. The final two criteria are concerned with adoption and implementation; ensuring the system is both useful to and useable by the developer/researcher.

We subsequently designed an audit trail system that sought to address each of the above criteria. As most of the courseware produced within our unit is created using Macromedia Director® we elected to initially develop our system in and for that authoring environment. However, in keeping with our fourth design criteria – portability – we ensured that the system's architecture was structured in such a way so as to be readily adapted to a range of other scriptable multimedia authoring systems.

The resulting system is built around a library of functions that read and write individual records of user activities to a master record (the audit trail) within the target courseware. These functions interact with the other components of the system, which include client- and server-side administrative applications for transmitting and storing the audit trail data for later analysis. The library consists of a range of functions including timers, counters, item selection and data/text entry from which developers and researchers select according to their needs. Individual functions are attached to or associated with each of the objects to be audited within a piece of courseware and, when activated, these functions report to and dynamically update the audit trail record. The audit trail record can be exported at any time, although this process typically occurs when the user quits the courseware.

As a pilot test of the system, we embedded it into a piece of biomedical courseware called Medical Genetix. The remainder of this paper describes the structure and use of the Medical Genetix courseware, our implementation of the audit trail system within it, and the various findings that emerged from this implementation.

The Structure and Use of Medical Genetix

Medical Genetix is used by medical students at the University of Melbourne to investigate biomedical and clinical aspects of genetic disorders such as cystic fibrosis and thallasaemia. Specifically, it is used as a self-directed learning resource to support students' investigation of particular medical problems or 'problems of the week' (Keppell, Elliott, & Harris, 1998; Keppell, Kennedy & Harris, 2000). Medical Genetix is available for students' use in the faculty's main computer labs as well as in tutorial rooms.

Medical Genetix consists of a number of sections and levels that students can easily move between. For example, material on the disorder cystic fibrosis is divided into three primary sections: Clinical Diagnosis, Laboratory Diagnosis and, Counselling and Ethics. The Clinical Diagnosis section is further broken down into Clinical Features, Family Histories and Pedigrees, and Molecular Pathogenesis. Each of these subsections has a series of screens comprising content and interactive tasks that allow students to review material, perform construction tasks, test their knowledge and understanding, or access further information as they require (Metcalfe, Williamson & Bonollo, 1999).

Medical Genetix was made available to second-year medical students to support their investigation of a problem of the week on cystic fibrosis. In the Family Histories and Pedigrees section of the courseware, students can access an interactive task involving the construction of a pedigree on the basis of a supplied family history. The family history details the relationship between family members and their status with regard to the genetic disorder cystic fibrosis (that is, whether family members were carriers, a proband, or had the disorder). The interactive pedigree is completed by dragging "tiles" designating these various states into the correct position in the pedigree on the basis of the supplied family history. Six types of tiles are available for students to use and there are a total of twenty positions to be filled in the pedigree (see Figure 1). If a student places a tile correctly in the pedigree it remains in its position and the name of the individual is displayed whereas incorrectly placed tiles are rejected and returned to their original position.

Figure 1: The interactive pedigree task illustrating the six types of tiles and a partially completed pedigree.

We embedded a selection of audit trail functions into the Family Histories and Pedigrees section of the Medical Genetix courseware, placing particular emphasis on the interactive pedigree task. The audit included which screens within the section were visited and, for the interactive pedigree task, the amount of time students spent on the task, a detailed record of which tiles were dragged, where and in what sequence they were placed, and the number of times students consulted the history and help screens.

Results

A total of 78 students accessed Medical Genetix during the week it was designated as a resource for the medical curriculum. Of these, 49 entered the Family History and Pedigree section; indicating that 29 students bypassed this section altogether. Of those 49 students, 42 arrived at the interactive pedigree. Eight of the 42 students who arrived at the interactive pedigree did not attempt the task. The remaining 34 students, who attempted the task, form the basis of the analyses below.

Activity	Mean	Minimum	Maximum
Total time on interactive pedigree†	257.86^	162.30	576.40
Number of correct drags	15.62	11	20
Number of incorrect drags	5.91	1	13
Number of incomplete drags	.09	0	1
Total time on history†	125.46	37.50	322.00
Average time on each history†	8.63	3.39	22.95
Number of times accessed history	15.44	5	27
Total time on help	8.11	2.80	24.00
Average time on each help	7.58	2.80	24.00
Number of times accessed help	.21	0	2

†two cases of the 34 were not included in this analysis because of incomplete data.
^all times are recorded in seconds.

Table 1: Summary statistics of students' use of the Interactive Pedigree derived from audit trail data.

Summary statistics of students' activities while completing the interactive pedigree are presented in Table 1. On average, students spent around four and a half minutes on the task, made a little over fifteen correct tile placements and made around six mistakes while attempting the task. They spent a little over two minutes on the history screen and most accessed it regularly (over 85% of the sample accessed it more than ten times). However, students did not access the help screen regularly or for any great length of time. Eighty-two percent of students did not access the help at all.

We were particularly interested in determining how students were attempting the interactive pedigree task. As a result we focussed our attention on the number of correct and incorrect tile placements (or "drags") that students completed. Table 2 presents frequency counts and percentages of students' correct and incorrect drags. It can be seen from this table that all students completed over half the task (ie. completed over 10 drags correctly) but only one student successfully completed the entire task (ie. completed 20 drags correctly). The average number of tiles correctly placed before students left the task was between 15 and 16 and this seems to be a critical point in the task in terms of students interest or persistence (see Table 1).

Correct Drags	Freq	%
11	1	2.9
12	1	2.9
13	3	8.8
14	4	11.8
15	8	23.5
16	6	17.6
17	5	14.7
18	3	8.8
19	2	5.9
20	1	2.9
Total	34	100

Incorrect Drags	Freq	%
1	2	5.9
2	2	5.9
3	6	17.6
4	6	17.6
5	3	8.8
6	2	5.9
7	2	5.9
8	3	8.8
9	3	8.8
10	1	2.9
11	0	0
12	1	2.9
13	3	8.8
Total	34	100

Table 2: Number of correct and incorrect tile placements ("drags") made by students

The fact that only one student fully completed the interactive pedigree task raises questions as to why the students were not completing the entire exercise. Was the task too difficult or did the students simply lose interest? We attempted to address this question by considering the proportion of correct tile placements made by students. The number of correct tile placements made by students was divided by the total number of tiles placed by students (ie correct and incorrect drags). The results of this analysis (Table 3) reveal that students had a high degree of success with their tile placements with two thirds of students returning a 70% or better success rate.

Proportion of Correct Drags	Freq	%
< 50%	1	2.9
51 - 60%	3	8.8
61 – 70%	7	20.6
71 – 80%	11	32.4
81 – 90%	10	29.4
91 - 100%	2	5.9
Total	34	100

Table 3: Proportion of correct tile placements made by students.

In addition to overall success rate, we analysed the final three tiles placed by students in the pedigree (regardless of how many tiles they placed in total). By assessing whether students were leaving the task after correctly or incorrectly placing tiles we sought an indication of whether students were losing interest in the task or found the task too difficult. An analysis of the last three tile placements is presented in Table 4.

These results indicate the overwhelming majority of students were leaving the task after performing well. Not one student placed all of the last three tiles incorrectly and 26 (76.5%) students placed their last three tiles correctly. Only one student left the task with an incorrect final drag, indicating that 33 (97.1%) students left the task with a correct final drag. This suggests that it was not the difficulty of the task that prevented students from completing it. Rather, given that students were successfully progressing within the task, their failure to complete it suggests that after a certain time they lost interest or had understood the point of the exercise. Further assessment is required to test this hypothesis further.

Status of the last three tiles placed by students	Freq	%
0 of last 3 tiles correct (0/3)	0	0
1 of last 3 tiles correct (1/3)	1	2.9
2 of last 3 tiles correct (2/3)	7	20.6
3 of last 3 tiles correct (3/3)	26	76.5
Total	34	100

Table 4: Analysis of the last three tiles placed by students

Discussion and Conclusions

The results of this pilot study demonstrate the utility of audit trails for gathering evaluation data for the purposes of usage audits and formative evaluation of instructional design. Audit trails provided valuable information on the degree to which Medical Genetix was being used by students as a resource to investigate the problem of the week (78 of 184 students (42.4%) used the courseware over one week) as well as detailed information about which sections of the courseware were being. The audit trail system is clearly able to provide course coordinators with critical and accurate information about the integration of courseware into their curriculum. This is particularly pertinent in student-centred curricula such as the medical degree at the University of Melbourne, which emphasises self-directed learning. Common evaluation techniques, such as self-report questionnaires and observation, struggle to adequately gather information on the resources students use as part of their self-directed learning due to inherent variation in the times and locations that students access resources. Using the audit trail system we developed, data can be gathered easily while maintaining flexibility and freedom of student access.

The audit trail system was used to formatively evaluate a specific interactive task (an interactive pedigree), and provided useful descriptive information. For example, of those students who attempted the task, all relied heavily on the provided history to complete the task but there was substantial variation in both the amount of time individual students spent on the history and the number of times they accessed it. The fact that the majority of students (82.4%) did not access a task specific help screen suggests the task was intuitive and well designed.

Undoubtedly, the most interesting result from this component of the study was that all but one student failed to complete the interactive pedigree task. This, coupled with evidence that students were, in general, successfully progressing within the task indicates the task was not too difficult. There are a number of possible explanations for this finding. Students may have simply found the task too long and lost interest in the exercise. Alternatively, they may have understood the "point" or message of the exercise part way through the task, removing the incentive to complete it. It is also possible that students had completed the pedigree on a previous occasion when using Medical Genetix as a resource in a earlier problem of the week.

The findings with regards to the interactive pedigree have implications for the instructional design of Medical Genetix as well as interactive tasks more generally. They suggest that attention should be given to length of interactive tasks and whether they are able to sustain students' interest. This is especially relevant if students are directed to different parts of the courseware on the basis of whether they complete a task or not. While decisions about the instructional design of interactive tasks should always be made with the target audience in mind (students' previous experience and prior knowledge), it is clear that audit trail data can inform the design of these tasks.

The success of this pilot implementation of the audit trail system validates our development of a generic yet flexible method of creating audit trails. By restricting the amount of information gathered using the systems' inbuilt functions (see Judd & Kennedy, 2001) and by focussing on a specific interactive task, we were not overwhelmed by data and were able to gather meaningful and useful information. Care should be taken not to over-interpret the data garnered from audit trails and additional data collection techniques should be used in conjunction with audit data to assist in the analysis and interpretation of results. This not withstanding, the judicious implementation of the audit trail component of our electronic evaluation system clearly has the capacity to inform and assist both developers and evaluators. The two further roles of audit trails outlined by Misanchuk and Schwier (1992) (research in instructional design and counselling and advising) are also possible with the audit trail system we have developed (Judd & Kennedy, 2001) and will be investigated in subsequent implementations of the system.

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